DOCUMENT RESUME

ED 385 228 IR 017 238

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TITLE Computer-Assisted Instruction and Conceptual Change.
PUB DATE Apr 95
NOTE 33p.; Paper presented at the Annual Meeting of the American Educational Research Association (San Francisco, CA, April 18-21, 1995).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Cognitive Processes; *Computer Assisted Instruction; Concept Formation; Foreign Countries; Geographic Concepts; Intermediate Grades; *Learning Activities; *Learning Strategies; Pacing; Problem Solving; Reading Comprehension
IDENTIFIERS *Conceptual Change

ABSTRACT

This study investigated the instructional conditions required to teach students how to initiate and employ learning activities aimed at conceptual change. The CONTACT-2 strategy (a computer-assisted instructional strategy for promoting conceptual change in the domain of physical geography) served as a starting point for a training procedure aimed at enhancing self-regulated learning. With the first experimental "scaffolding" condition, strategic support was gradually withdrawn per instructional step, while, with the second "scaffolding" condition, the number of steps was reduced as the training proceeded. Procedures for each experimental condition are outlined. Subjects were 65 fifth- and sixth-graders assigned to one of three groups: the experimental condition "scaffolding per instructional step," "scaffolding of the number of steps," and CONTACT-2 control condition. The effects of the between-subjects factor instruction on the quality of students' conceptions during seven training sessions were measured by means of idea questions, concrete problems that had to be solved by relating central concepts from the corresponding training text. Dependent variables concerned quality of conceptions, learning performance, and students' ability to initiate and employ learning activities aimed at conceptual change. Results indicated that scaffolding is a fruitful instructional approach to foster self-regulated learning aimed at conceptual change, provided that the scaffolding procedure is tuned to students' actual level of self-regulated learning: external control should not be faded until students are able and prepared to initiate and employ the required learning activities. When these conditions are met, it seems possible to design effective training procedures aimed at learning for conceptual change. Two tables and nine figures illustrate data. (Contains 38 references.)
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Computer-Assisted Instruction and Conceptual Change

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Paper presented at
the Annual Meeting of the American Educational Research Association
(S.I.G. Subject-Matter Knowledge and Conceptual Change)

San Francisco, April 21, 1995

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Computer-Assisted Instruction and Conceptual Change

Harm J.A. Biemans & P. Robert-Jan Simons

Abstract

In this study, the question was addressed which instructional conditions are required to teach students how they can initiate and employ learning activities aimed at conceptual change themselves. The CONTACT-2 strategy (a computer-assisted instructional strategy for promoting conceptual change in the domain of physical geography) served as starting point for a training procedure aimed at enhancing self-regulated learning. With the first experimental "scaffolding" condition, strategic support was gradually withdrawn per instructional step, while, with the second "scaffolding" condition, the number of steps was reduced as the training proceeded. The original CONTACT-2 condition served as control condition. Subjects were 65 fifth- and sixth-graders (primary education). Dependent variables concerned quality of conceptions, learning performance as well as students' ability to initiate and employ learning activities aimed at conceptual change. Results indicated that "scaffolding" is a fruitful instructional approach to foster self-regulated learning aimed at conceptual change, provided that the "scaffolding" procedure is tuned to students' actual level of self-regulated learning: external control should not be faded until students are able (and prepared) to initiate and employ the learning activities being required. When these conditions are met, it seems possible to design effective training procedures aimed at "learning for conceptual change".

Computer-Assisted Instruction and Conceptual Change

Harm J.A. Biemans & P. Robert-Jan Simons

Introduction

The idea that learning should be active is widespread among educational researchers already: one of the assumptions of many recent theories of learning and instruction is that knowledge and skills can not be transferred in a direct way but result from mental activities, undertaken by the learner (e.g., Resnick, 1989; Duffy and Jonassen, 1991; De Jong, 1992; Vermunt, 1992). The quality of learning performance appears to be dependent on the quality of his/her learning activities (see also Biemans and Simons, 1992).

One of the essential aspects of active learning is searching for and using prior knowledge in understanding new information: constructivist learning theories (e.g., Hegland and Andre, 1992) consider the active use of prior knowledge to be a key strategy for constructing rich and useful mental representations. Prior knowledge can be described as all knowledge learners have when entering a learning environment, that is potentially relevant for acquiring new knowledge (see also Biemans and Simons, 1995). In this paper, the question is addressed which instructional conditions are required to teach students how they *themselves* can activate their prior knowledge and initiate and employ learning activities aimed at conceptual change. In other words, how can instructional systems teach students to use their correct or partially correct prior knowledge without creating interference and at the same time to deal with incorrect (i.e. not in accordance with generally accepted scientific views) or partially incorrect prior knowledge that tends to resist change (see Eylon and Linn, 1988)? At this point, it should be noted that generally accepted scientific views especially exist in well-structured knowledge domains, for example the domain of basic physical geography that has been treated in our studies. In our view, the distinction between incorrect and correct conceptions is far less clear when advanced knowledge acquisition in ill-structured domains is concerned (see also Spiro, Feltovich, Jacobson and Coulson, 1991).

Inspired by current conceptual change approaches (e.g., Nussbaum and Novick, 1982; Hewson and Hewson, 1984; Strike and Posner, 1985, 1992; Prawat, 1989; Pintrich, Marx and Boyle, 1993; Duit, 1994), several instructional strategies aimed at prior knowledge activation and conceptual change were created by Ali (1990) and the authors of this chapter (Biemans and Simons, in press; in preparation).

Ali (1990) designed and evaluated the CONTACT strategy, typified by continuous, computer-assisted activation of the conceptions of individual learners (sixth-graders, primary education) in text processing (domain: physical geography). The strategy was based on an instructional model consisting of five steps aimed at conceptual change: students should 1) be helped in searching their own relevant preconceptions (through an exposing event); 2) be activated to compare and contrast their preconceptions with the new information; 3) be stimulated to formulate a new conception, based on the previous step; 4) to apply the new conception in a concrete problem; and 5) to evaluate the adequacy of the new conception in relation to step 4 (see also Biemans and Simons, 1995). The CONTACT strategy appeared to be more effective in fostering conceptual change than a strategy characterized by activation both before and after the presentation of the new textual information. In a previous study, this before-after strategy had been proved to be more effective than no activation or activation at either the beginning or the end of the training session (see also Ali, 1990).

In our first study (see Biemans and Simons, in press), the effects of the various CONTACT steps were examined by dismantling the strategy. An experiment with 86 subjects (fifth- and sixth-graders, primary education) was conducted with four instructional strategy conditions, varying with respect to the number of instructional steps: 1) complete CONTACT condition (a. search for preconceptions; b. compare and contrast their preconceptions with the new information from the learning task; c. formulate a new conception; d. apply the new conception; e. evaluate the new conception); 2) NEW IDEA condition (a. search for preconceptions; b. compare and contrast their preconceptions with the new information from the learning task; c. formulate a new conception); 3) OLD IDEA condition (a. search for preconceptions); and 4) NO ACTIVATION control condition. A mixed design was used with 2 between-subjects factors (instructional condition and students' familiarity with the central concepts from the 7 expository texts used) and 2 within-subjects factors (type of

learning performance test item -directly related/less directly related to the central concepts from the texts- and time of testing -posttest/retention test-). Dependent variables concerned quality of conceptions and learning performance. Results indicated that the complete CONTACT strategy was the most effective instructional strategy for promoting conceptual change (especially for "highly familiar" students) because students who had been assigned to this instructional condition constructed more correct conceptions (i.e. in accordance with generally accepted scientific views). However, they mainly seemed to focus on the central concepts from the texts, disregarding information that was less directly related to these concepts (see also Machiels-Bongaerts, 1993).

Therefore, in our second study (see Biemans and Simons, in preparation), the CONTACT strategy was adapted to solve this problem of selective attention and to increase its effectiveness. Subjects (74 fifth- and sixth-graders) were assigned to three instructional conditions (original CONTACT condition, revised CONTACT-2 condition and control condition NO ACTIVATION). A mixed design was used with the same between- and within-subjects factors as in the first study. Dependent variables again concerned quality of conceptions and learning performance. Students from the CONTACT-2 condition constructed better conceptions and achieved higher learning performance scores than students from the other two conditions. Based on the findings of this study, one could conclude that the CONTACT-2 strategy was more effective as instructional strategy aimed at conceptual change than the other two conditions because the students constructed conceptions that more accurately represented the relations between the central concepts from the learning task. Therefore, this study provided additional empirical support for the underlying activation model (see also Ali, 1990). Moreover, the effectiveness of the CONTACT-2 strategy appeared not to be dependent on the degree of conceptual resemblance between the performance test questions and the central concepts from the texts and on the moment of testing. Thus, the adaptations of the CONTACT strategy did indeed result in an increase in efficiency and flexibility of the strategy and in an adequate solution to the problem of selective attention.

However, with this conclusion, other questions arise. Although our second study showed that it is possible to help fifth- and sixth-graders (primary education) to use their prior knowledge actively by means of a process-oriented instructional strategy

presented through computer-assisted instruction, it is still unclear, however, what exactly causes the effectiveness of the strategy. A rather complex learning environment was designed that turned out to be effective in promoting conceptual change. But what are the essential ingredients? Can some of the steps and instructional measures be skipped? Can stripped versions of the strategy also be made effective? New dismantling studies seem necessary to answer these -and other- questions (see also Biemans and Simons, 1995).

In our third study, however, these lines of research were not be pursued. Instead, we focused on another aspect of the CONTACT-2 strategy: the high degree of external control. As had been shown in the second study, a high degree of external control can result in conceptions of higher quality and in better learning performance, but it may also lead to higher dependence on external support. In our view, high dependence on external support can be an undesirable side effect of an (any) instructional strategy in the longer term: without external help, students may not be able to initiate and employ the particular learning activities themselves and, thus, to achieve the learning goals (see also Vermunt, 1992). Therefore, we decided to elaborate on this aspect of instructional strategies aimed at conceptual change.

Following Shuell (1988), five learning functions were distinguished that have to be performed to ensure adequate learning (see Simons, 1991): 1) preparing learning; 2) taking learning steps; 3) regulating learning; 4) providing feedback and judgment; and 5) maintaining concentration and motivation. Each of these learning functions includes various activities that can be undertaken either by the learner or by an external source (e.g., the teacher or CAI program), depending on the way the learning situation is organized (see also Biemans and Simons, 1992).

In case of direct teaching, learning functions are fulfilled by an external source. These learning situations are characterized by a high degree of external control: the external source mainly initiates and fulfils the learning functions. A second option is activation of the learning functions which pertains to forcing the learner to undertake the corresponding learning activities in a specified way. In this case, the degree of external control is still relatively high: learning functions are initiated and structured by the external source through the presentation of assignments to be performed by the learner. Another way in which instructional systems can influence learning functions is by

stimulation which involves either providing general advice to execute certain learning activities or training the learner to fulfil learning functions. Compared to the option of activation, stimulation is typified by less external control: the learner is stimulated to initiate and perform the corresponding activities. Finally, if the student is able to fulfil learning functions in an adequate way with a low degree of external support, learning is self-regulated.

Many training programs have been developed to improve self-regulation skills (see Nisbet, 1989). These training programs differ considerably with respect to the degree of external control provided by the learning environment. Some programs are characterized by a high degree of external control, while, with other training procedures, learners have to rely on themselves to a higher extent (see Wittrock, 1990). Another option is a gradual transfer of the responsibility for learning processes from the learning environment to the learner ("scaffolding") (Reeve, Palincsar and Brown, 1987): "fading" of external control is one of the main principles of the "cognitive apprenticeship" approach (Brown, Collins and Duguid, 1989).

De Jong's (1992) C.A.I. programs that were embedded in regular reading courses, were typified by "fading" of external regulation as well. Supported by regulation questions and hints, students had to regulate their own learning process based on knowledge about regulation activities (see also Biemans, 1989). The regulation hints (the "What", "How" and "Why" parts of the regulation heuristic) contained information about what was meant by a particular learning activity, about ways to perform this activity and about the reasons why it was important to do so ("informed training"): Paris, Newman and McVey (1982) had shown that "informed training" leads to more adequate strategy use and to higher learning performance than "blind training". During the first part of the training (see De Jong, 1992), the programs provided regulation questions and hints and checked at regular times whether the student was using the regulation heuristic. These interventions were "scaffolded" during the second part of the training: the frequency of their occurrence decreased (see Reeve, Palincsar and Brown, 1987). Finally, interventions stopped completely. The training had positive effects on learning activities and learning performance of students from secondary schools; for students from primary schools and learning-disabled students, however, effects of the training were poor (De Jong, 1992). Probably, their cognitive and/or

reading comprehension level was a crucial explanatory factor (see also Brown and Barclay, 1976; Garner, 1988). An additional explanation, especially with respect to learning-disabled students, could be that the training did not take affective, volitional and motivational factors into account that impeded active, adequate learning (see Corno, 1988).

However, De Jong's (1992) studies showed that training procedures based on regulation questions and hints can be successful in terms of learning activities and performance. Similar findings were reported by other researchers like Salomon (1988), Wade and Trathen (1989) and Van Deursen (1991): embedding regulation questions and hints can enhance the adequacy of strategy use and lead to better learning performance. Besides, these studies proved that the computer can be used to train self-regulation (see also De Klerk and Verschaffel, 1990).

In a previous study (see for more details Biemans and Simons, 1992), we focused on the effects of regulation questions and hints as such on students' learning activities and learning performance (second graders, lower vocational education). Therefore, in this study, regulation help was not "faded" as the training proceeded. The training was aimed at learning to use a word-processor. Regulation questions and hints were embedded in a concurrent C.A.I. program, also providing content help on word-processing: the instructional shell WP-DAGOGUE controlled the interaction between student and word processor. The three instructional conditions varied with respect to the degree in which the learning function "regulating learning" was fulfilled by the instructional shell: 1) content help plus regulation questions plus regulation hints; 2) content help plus regulation questions; and 3) content help only. All regulation questions and hints corresponded to a particular part of the training heuristic (see Biemans, 1989) and were aimed at planning, testing, monitoring and evaluating (see De Jong and Simons, 1990).

The combination of regulation questions and corresponding regulation hints appeared to lead to higher learning performance after the training than the other two instructional conditions. Therefore, the conclusion seems justified that regulation questions and hints can serve as supportive instructional strategies for the purpose of increasing understanding. This study also proved that embedding regulation questions and regulation hints in the learning environment can enhance learning performance not

only in reading (as shown in the studies mentioned above) but also in the domain of word-processing. Embedding regulation questions only, however, did not result in higher learning performance: adding regulation hints was necessary to achieve this. Students did not seem to be able (yet) to perform the corresponding learning activities without these activities being initiated through regulation hints. Apparently, embedding both regulation questions and regulation hints resulted in "constructive frictions"; posing regulation questions only, on the other hand, resulted in "destructive frictions" (see Vermunt, 1992).

This study, however, also showed that students who had been assigned to the instructional condition "Content help plus regulation questions plus regulation hints" (characterized by the highest degree of external control) reported an increased dependence on external control hints (see for more details Biemans and Simons, 1992). In other words, more extensive regulation help appeared to lead to higher learning performance, but also to higher dependence on external support.

As mentioned above, in our view, high dependence on external support should be considered as an undesirable side effect of an (any) instructional strategy in the longer term: without external help, students may not be able to initiate and employ the particular learning activities themselves and, thus, to achieve the learning goals (see also Vermunt, 1992). The ultimate goal should be to teach students how to initiate and perform learning activities themselves (see also Jonassen, 1991): independence of external control is one of the core characteristics of self-regulated learning (see also Simons, 1991; Vermunt, 1992). Therefore, we believe that gradually transferring the responsibility for learning processes from the learning environment to the learner ("scaffolding") is a promising approach for promoting self-regulated learning (see also Reeve, Palincsar and Brown, 1987).

Research questions and hypotheses

The following hypotheses with respect to "scaffolding" approaches aimed at promoting self-regulated learning were formulated (see Biemans and Simons, 1992, p. 335): "... "scaffolding" seems to be the most promising approach to reach this goal, provided that it is based on the actual level of self-regulated learning of the student. If the

external support is withdrawn without the student being able (or prepared) to perform regulation activities, weaker learning performance, in our opinion, is inevitable. However, if "scaffolding" is tuned to the self-regulation knowledge and skills of the student, ... the quality of self-regulated learning as well as learning performance can be improved." These hypotheses were tested in our third conceptual change study. In this study, the following research question was addressed: which instructional conditions are required to teach students how they *themselves* can initiate and employ learning activities aimed at conceptual change?

The CONTACT-2 strategy (see for more details Biemans and Simons, in preparation) served as starting point for a "learning-to-learn" training procedure aimed at enhancing self-regulated learning (see also Jonassen, 1991). This "learning-to-learn" approach was also chosen because of another reason: it would be impossible to design instructional programmes for all subject matter following the CONTACT-2 strategy. Therefore, in our view, it is preferable to teach students how to use the steps of the strategy on their own or, in other words, to teach students how to activate their own preconceptions and how to construct correct conceptions. The main goal of this study was to examine to what extent the learning activities corresponding to the various steps of the CONTACT-2 strategy can be learned (domain and target population were the same as in the first two studies).

The CONTACT-2 strategy was implemented in a computer-assisted training procedure aimed at teaching students how to employ the various CONTACT-2 activities themselves. Therefore, external control was gradually withdrawn ("scaffolding"). With the first experimental "scaffolding" condition, the amount of strategic support was gradually withdrawn per instructional step while, with the second "scaffolding" condition, the number of steps was reduced as the training proceeded. Moreover, students from both "scaffolding" conditions were informed about the training goals (see also Paris, Newman and McVey, 1982; De Jong, 1992): learning how to activate their own preconceptions and how to construct correct conceptions themselves. The CONTACT-2 condition from the second study served as control condition. Again, dependent variables concerned quality of conceptions and learning performance (see for more details Biemans and Simons, in preparation). Students' ability to initiate and employ

learning activities aimed at conceptual change with a low degree of external support and without external control was measured in two additional sessions.

Our hypotheses with respect to the intervention effects mainly pertained to the variables that were registered during these two testing sessions. We hypothesised that both "scaffolding" conditions would be more effective than the CONTACT-2 control condition that was characterized by a constant, high degree of external control: because of "fading" external control, the "scaffolding" conditions would prepare students to a higher extent to employ the various CONTACT-2 activities themselves. Moreover, during the training, these students were informed that they had to learn to activate their own prior knowledge and to construct correct conceptions without external support. Therefore, we assumed that both experimental "scaffolding" conditions would lead to conceptions of a higher quality and to higher learning performance than the CONTACT-2 control condition.

With respect to the two experimental conditions, we hypothesised that the condition "scaffolding per instructional step" would be more effective than the condition "scaffolding of the number of steps". We assumed that reducing the number of instructional steps ("scaffolding of the number of steps") would probably be too drastic: if external support is withdrawn without the student being able (or prepared) to perform the corresponding learning activities, "destructive frictions" and poorer learning performance, in our opinion, are likely to be the result (see Lohman, 1986; Vermunt, 1992). We expected that the other experimental condition ("scaffolding per instructional step"), in which the number of instructional steps stays constant but external control is reduced per step, would be better tuned the actual level of self-regulated learning of the student (see Biemans and Simons, 1992). Therefore, we assumed that this "scaffolding" condition would result in "constructive frictions" and higher learning performance (see Lohman, 1986; Vermunt, 1992).

With respect to training sessions data, we assumed that the stage of the "fading" procedure would affect the quality of conceptions and learning performance (in the two "scaffolding" conditions, external control was "faded" in four stages). In other words, we hypothesised that differences between the various instructional conditions would depend on the stage of the training.

Whereas, in our previous conceptual change study, both quality of final conceptions and learning performance had been proved not to depend on the degree of students' familiarity with the central concepts from the training texts, this factor was not included in the design of the present study. For the same reason, learning performance test questions were not classified as directly related to the central concepts of the corresponding training text or as less directly related (see for more details Biemans and Simons, in preparation).

Method

Subjects

Subjects were 65 students, being 10 to 13 years old and attending three different combination classes of two primary schools (30 fifth- and 35 sixth-graders). After being matched based on their competence level (reading comprehension as judged by their teacher) and their grade, subjects were assigned to the three instructional conditions at random.

Instructional conditions

Subjects were assigned to three instructional conditions: the experimental condition "scaffolding per instructional step" (N=21), the experimental condition "scaffolding of the number of steps" (N=22) and the CONTACT-2 control condition (N=22). The CONTACT-2 condition was identical to the condition of the same name used in the previous study (see for more details Biemans and Simons, in preparation).
The "scaffolding" procedure for the first experimental condition "scaffolding per instructional step" was the following:

- at the beginning of the training, students were supported by the complete CONTACT-2 strategy from the previous study (stage 1: introduction session and first training session);
- during the next two sessions, students were supported by regulation questions and regulation hints (the "How" and "Why" parts): monitoring questions ("Do

you understand what to do with this step?") were omitted (stage 2: second and third training session);

- during the next two sessions, students were only supported by regulation questions: regulation hints were omitted (stage 3: fourth and fifth training session);
- during the last two training sessions, regulation questions were "faded" as well: only the "execution screens" corresponding to the various CONTACT-2 steps were provided (stage 4: sixth and seventh training session).

For the second experimental condition "scaffolding of the number of steps", the following "scaffolding" procedure was used:

- at the beginning of the training, students were supported by the complete CONTACT-2 strategy from the previous study (stage 1: introduction session and first training session) (see experimental condition "scaffolding per instructional step");
- during the next two sessions, students were supported by the various CONTACT-2 steps without feedback loop in case of an incorrect new conception or a negative evaluation (stage 2: second and third training session);
- during the next two sessions, students were supported by the first three CONTACT-2 steps: the steps "apply the new conception" and "evaluate the new conception" were omitted (stage 3: fourth and fifth training session);
- during the last two training sessions, only the first CONTACT-2 step "search for preconceptions" was presented: the steps "compare and contrast the preconceptions with the new information from the learning task" and "formulate a new conception" were omitted (stage 4: sixth and seventh training session).

Before and during the training, students from both "scaffolding" conditions were informed about the goals of the training: learning how to activate their own preconceptions and how to construct correct conceptions themselves, without external support.

Design and materials

In the experimental design the factor Instruction was used as the between-subjects factor. The factor Instruction had three levels: the condition "scaffolding per instructional step" (condition 1), the condition "scaffolding of the number of steps" (condition 2) and the CONTACT-2 condition (condition 3) (see section "Instructional conditions").

The effects of the between-subjects factor Instruction on the quality of students' conceptions during the seven training sessions were measured by means of idea questions. An idea question could be described as a concrete problem that had to be solved by relating the central concepts from the corresponding training text. Each student had to choose from six answer alternatives that corresponded to different ideas about the relations between the concepts involved in the problem (see Biemans and Simons, in preparation). The answer alternatives were based on various conceptions that had been determined as being frequently held by students in the domain of physical geography (see Ali, 1990). One of the answer alternatives corresponded to the scientific notion as explained in the text. Students had to state their conception both at the beginning and at the end of each training session. Mean scores were calculated for each of the four "scaffolding" stages of the training (see Table 1).

As in our previous study (see Biemans and Simons, in preparation), the quality of students' conceptions after the seven training sessions as well as their ability to apply these conceptions were also measured after the training. Immediately after each of the seven training sessions, all subjects answered the particular idea question. Moreover, they answered two practice questions treating the same concepts and relations between concepts. The same questions were posed two weeks after the last training session. Again, mean scores were calculated for each of the four "scaffolding" stages (see Table 1).

The effects of the between-subjects factor Instruction on learning performance after the seven training sessions were measured by means of a posttest that was administered immediately after the corresponding training session and a retention test that was delivered two weeks after the last training session. Once more, mean scores were

calculated for each of the four "scaffolding" stages (see Table 1; for more details Biemans and Simons, in press; in preparation).

	Within-subjects factor(s)	Levels
Conceptions during training	Training Time	Preconception Final conception
	Training Stage	Stage 1 Stage 2 Stage 3 Stage 4
Conceptions after training + ability to apply	Training Stage	Stage 1 Stage 2 Stage 3 Stage 4
	Testing Time	Immediately after training After two weeks
Learning performance	Training Stage	Stage 1 Stage 2 Stage 3 Stage 4
	Testing Time	Posttest Retention test

Table 1: Within-subjects factors with respect to the training sessions data (mean scores were calculated by dividing the sum scores by the number of questions).

In addition to the seven training lessons, students also had to study two other texts. These texts were used to examine to what extent students themselves could initiate and employ learning activities aimed at conceptual change. During the first of these two testing sessions, students had to employ the various CONTACT-2 activities without the support of regulation questions and regulation hints (see "Instructional conditions"): only the "execution screens" corresponding to the various CONTACT-2 steps were

provided. During the second testing session, students' conceptions were only activated before and after studying the text: in this case, students themselves had to initiate the other CONTACT-2 activities without external support. For both testing sessions, the following dependent variables were measured: conceptions at the beginning and the end of each session, quality of students' conceptions after the session as well as their ability to apply these conceptions and learning performance (see Table 2).

	Within-subjects factor/ Dependent variable (*)	Levels
Conceptions during session	Session Time	Preconception Final conception
Conceptions after session + ability to apply	Testing Time	Immediately after session After two weeks
Learning performance	Mean score (*)	

Table 2: Within-subjects factors and dependent variables with respect to the testing sessions data (mean scores were calculated by dividing the sum scores by the number of questions).

Procedure

The procedure of this experiment was comparable to the procedure of the previous studies (see Figure 1; for more details Biemans and Simons, in press; in preparation). The seven training texts were all relatively short (7-8 text screens plus 2-3 pictures; 400-550 words). The texts dealt with physical geography, treating concepts like equator, earth rotation, rain, wind, atmospheric pressure, etc. Each student was allowed the time he/she needed to study the text screens and to employ the learning activities corresponding to the steps of the instructional strategy.

Session 1	Introduction session
Session 2 - 8	Training sessions + posttest + idea and practice questions
Session 9	Testing session A + posttest + idea and practice questions
Session 10	Testing session B + posttest + idea and practice questions
Session 11	Retention test + idea and practice questions

Figure 1: Procedure of the present study.

Results

Training sessions

To explore the intervention effects on the quality of students' conceptions during the seven training sessions, a repeated measurement ANOVA with the between-subjects factor Instruction and the two within-subjects factors Training Time and Training Stage was carried out. The main effect of the factor Instruction ($F(2,62)=1.02;p=.37$) and the interaction effect between Instruction and Training Stage ($F(6,118)=1.75;p=.12$) were not significant. The interaction effect between Instruction and Training Time ($F(2,62)=4.31;p\leq.05$), on the other hand, was significant. The interaction effect between Instruction, Training Time and Training Stage ($F(6,118)=3.90;p\leq.001$), however, was significant as well. With respect to the quality of students' preconceptions, no differences between the various instructional conditions were found (see Figure 2a). Concerning the quality of their final conceptions, however, such differences could be determined, depending on the stage of the training: the stage of the "fading" procedure affected the quality of students' developing conceptions. During the first stage of the training, condition 2 led to final conceptions of a higher quality than the other two conditions. During the next stages,

however, condition 1 led to the best final conceptions. The quality of the final conceptions of the students from condition 2 decreased dramatically, as the training proceeded (see Figure 2b).

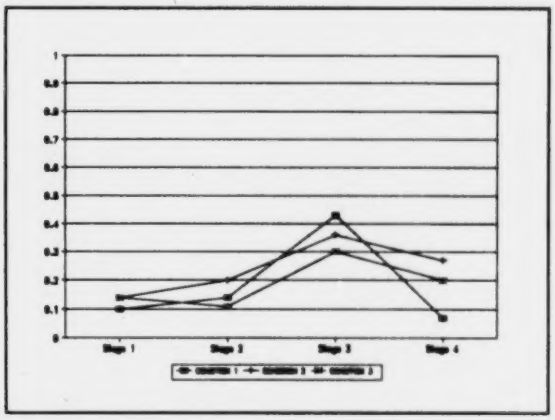

Figure 2a: Mean scores for the three instructional conditions with respect to the quality of the preconceptions (training sessions).

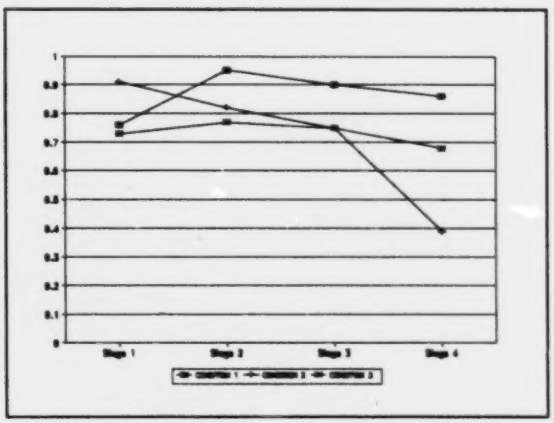

Figure 2b: Mean scores for the three instructional conditions with respect to the quality of the final conceptions (training sessions).

To examine whether the training had an effect on the quality of students' conceptions after the seven training sessions and on their ability to apply these conceptions, a repeated measurement ANOVA with the between-subjects factor Instruction and the two within-subjects factors Training Stage and Testing Time was carried out. The main

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effect of the factor Instruction ($F(2,62)=1.81;p=.17$) was not significant. The interaction effect between Instruction and Training Stage ($F(6,118)=2.44;p\leq.05$), however, turned out to be significant. During the first half of the training, the conditions 1 and 2 led to higher scores on the idea and practice questions than condition 3. During the second half of the training, however, scores of the students from the three conditions became more and more comparable (see Figure 3). Both the interaction effect between Instruction and Testing Time ($F(2,62)=.22;p=.80$) and the interaction effect between Instruction, Training Stage and Testing Time ($F(6,118)=.98;p=.44$) were not significant. Thus, the relation between instructional condition and training stage was both found at posttest time and at retention time.

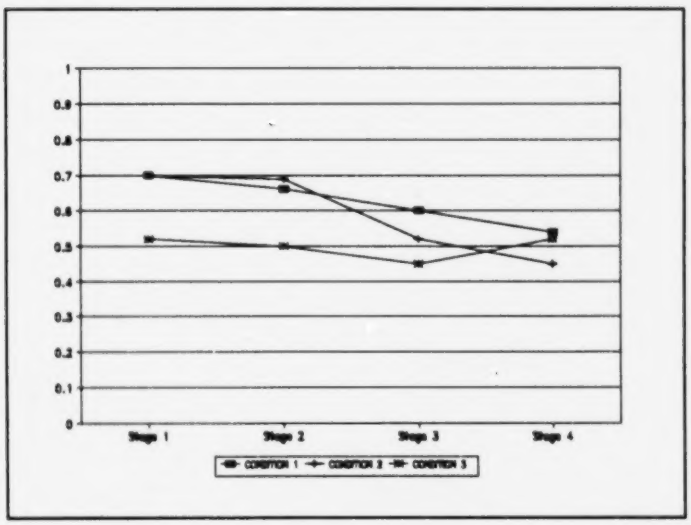

Figure 3: Mean scores for the three instructional conditions with respect to the idea and practice questions (training sessions).

To determine the training effects on students' learning performance after the seven training sessions, a repeated measurement ANOVA with the between-subjects factor Instruction and the two within-subjects factors Training Stage and Testing Time was carried out. Again, the main effect of the factor Instruction ($F(2,62)=1.96;p=.15$) was not significant while the interaction effect between Instruction and Training Stage ($F(6,118)=3.89;p\leq.001$) turned out to be significant. During the first half of the training, the conditions 1 and 2 led to higher learning performance scores than

condition 3 while, during the second half of the training, scores of the students from the three conditions became more and more comparable (see Figure 4). Both the interaction effect between Instruction and Testing Time ($F(2,62)=.40;p=.67$) and the interaction effect between Instruction, Training Stage and Testing Time ($F(6,118)=1.01;p=.42$) were not significant. Thus, the relation between instructional condition and training stage again did not depend on the moment of testing.

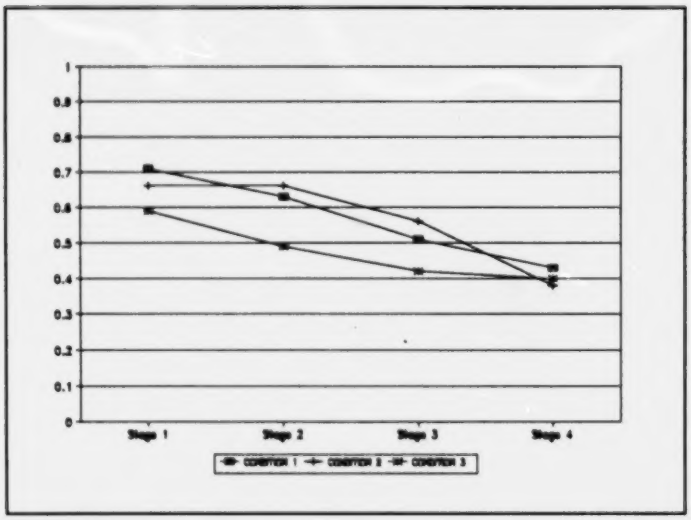

Figure 4: Mean scores for the three instructional conditions with respect to the learning performance tests (training sessions).

In addition to the seven training lessons, students also had to study two other texts. These texts were used to examine to what extent students themselves could initiate and employ learning activities aimed at conceptual change (see section "Design and materials"). For both testing sessions, the following dependent variables were measured: conceptions during the session, quality of students' conceptions after the session as well as their ability to apply these conceptions and learning performance.

Testing session A

Conceptions during the session

The main effect of the factor Instruction ($F(2,62)=.30;p=.74$) was not significant. The interaction effect between Instruction and Session Time ($F(2,62)=3.14;p\leq.05$), however, turned out to be significant. No differences were found between the conditions 1 and 2 with respect to the quality of preconceptions. Students from condition 1, however, had final conceptions of a higher quality than students from condition 2 ($t=2.50;p\leq.05$) (see Figure 5a). Interaction effects were not significant for conditions 1 and 3 ($t=1.35;p=.18$) and conditions 2 and 3 ($t=1.17;p=.25$).

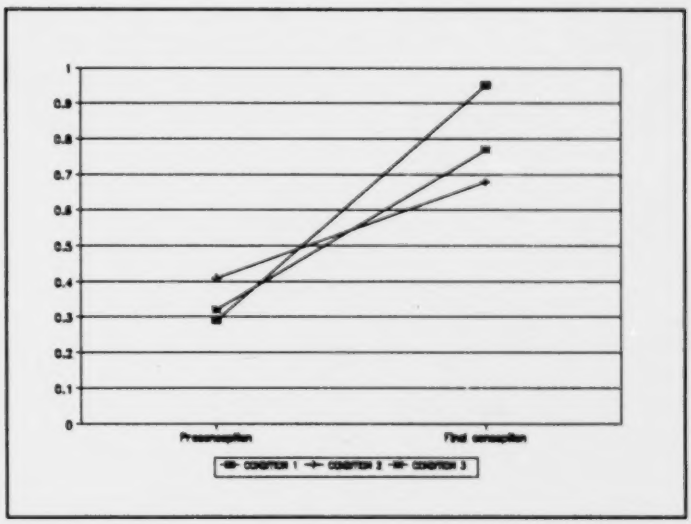

Figure 5a: Mean scores for the three instructional conditions with respect to the quality of preconceptions and final conceptions (testing session A).

Conceptions after the session and ability to apply these conceptions

In this case, the main effect of the factor Instruction ($F(2,62)=3.26;p\leq.05$) was significant. Students from condition 1 had higher scores on the idea and practice questions than students from condition 2 ($t=2.53;p\leq.01$) (see Figure 5b). Differences between conditions 1 and 3 ($t=1.62;p=.11$) and conditions 2 and 3 ($t=.92;p=.36$) were

not significant. The interaction effect between Instruction and Testing Time ($F(2,62)=.40;p=.67$) was not significant.

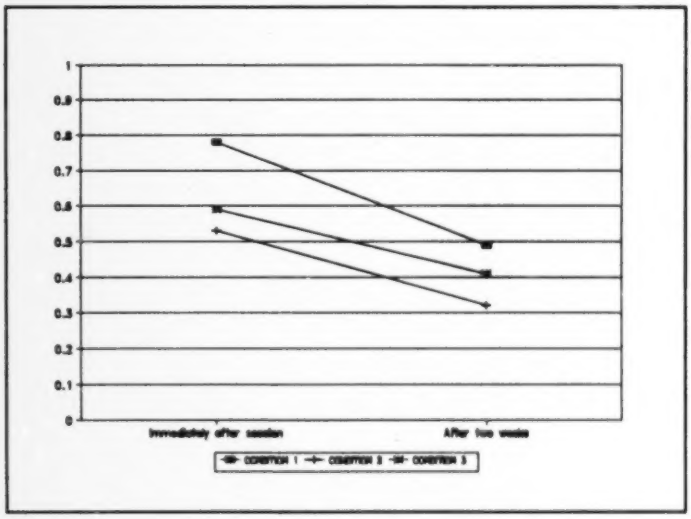

Figure 5b: Mean scores for the three instructional conditions with respect to the idea and practice questions (testing session A).

Learning performance

The effect of the factor Instruction ($F(2,62)=.41;p=.67$) on learning performance was not significant: no differences were found between condition 1 ($M=.45;Sd=.22$), condition 2 ($M=.46;Sd=.16$) and condition 3 ($M=.41;Sd=.21$).

Testing session B

Conceptions during the session

In this case, the main effect of the factor Instruction ($F(2,62)=4.74;p\leq.01$) was significant. Students from condition 1 had conceptions of a higher quality than students from condition 3 ($t=3.08;p\leq.005$) (see Figure 6a). Differences between conditions 1 and 2 ($t=1.59;p=.12$) and conditions 2 and 3 ($t=1.51;p=.14$) were not significant. The

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interaction effect between Instruction and Session Time (F(2,62)=1.16;p=.32) was not significant.

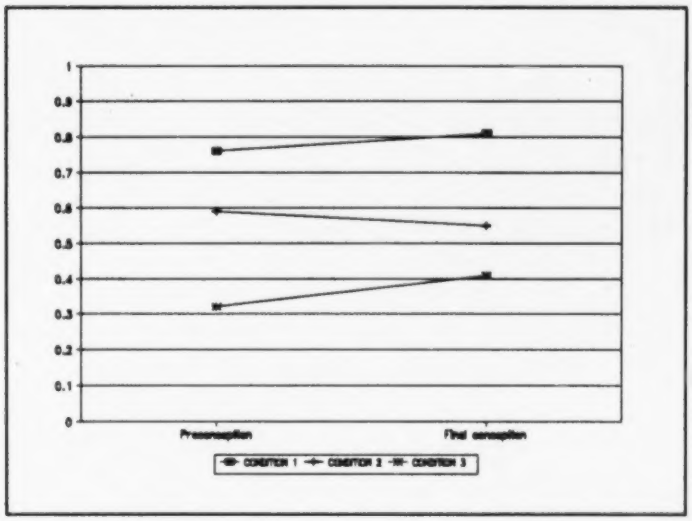

Figure 6a: Mean scores for the three instructional conditions with respect to the quality of preconceptions and final conceptions (testing session B).

Conceptions after the session and ability to apply these conceptions

The main effect of the factor Instruction (F(2,62)=2.19;p=.12) was not significant: no significant differences could be determined between the various instructional conditions (see Figure 6b). The interaction effect between Instruction and Testing Time (F(2,62)=1.47;p=.24) was not significant either.

Learning performance

The effect of the factor Instruction (F(2,62)=3.36;p≤.05) on learning performance was significant. Students from condition 1 (M=.49;Sd=.23) had higher learning performance scores than students from condition 3 (M=.36;Sd=.15) (t=2.07;p≤.05). The same held for students from condition 2 (M=.51;Sd=.25) (t=2.38;p≤.05). The difference between conditions 1 and 2 (t=.28;p=.78) was not significant.

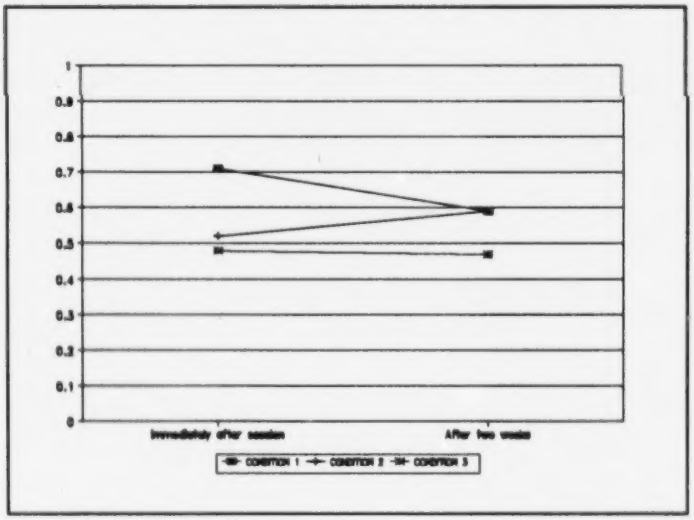

Figure 6b: Mean scores for the three instructional conditions with respect to the idea and practice questions (testing session B).

Conclusions and discussion

In the present study, several hypotheses were tested (see also Biemans and Simons, 1992). First, we assumed that both "scaffolding" conditions would lead to conceptions of a higher quality and to higher learning performance than the CONTACT-2 control condition. Moreover, we hypothesised that the condition "scaffolding per instructional step" would be better tuned the actual level of self-regulated learning of the students than the condition "scaffolding of the number of steps": we expected that the condition "scaffolding of the number of steps " would result in "destructive frictions" and, thus, in conceptions of a lower quality and in lower learning performance.
During the first testing session, students had to employ the various CONTACT-2 activities without the support of regulation questions and regulation hints. External support was provided in the form of the "execution screens" corresponding to the various instructional steps. During the last two training sessions for students from the condition "scaffolding per instructional step", regulation questions and hints had been faded as well and only the "execution screens" were provided. Thus, for them, the degree (and kind) of external control in the last two training sessions and the first

testing session were comparable: with these three sessions, they had to rely on themselves to the same extent. During the last two training sessions for students from the condition "scaffolding of the number of steps", however, only the first step "searching for preconceptions" was presented. Therefore, for these students, the degree (and kind) of external control in the first testing session did not match. Apparently, this resulted in "destructive frictions" and, thus, in conceptions of a lower quality as compared to the condition "scaffolding per instructional step" (see also Lohman, 1986; Vermunt, 1992). Students from the condition "scaffolding per instructional step", on the other hand, seemed to be better prepared to employ learning activities aimed at conceptual change under these circumstances: they had final conceptions of a higher quality and were more successful in applying these conceptions. The test scores of the students from the CONTACT-2 control condition were also lower than the scores of the students from the experimental condition "scaffolding per instructional step" but these differences were not significant.

With the second testing session, however, students from the condition "scaffolding per instructional step" had conceptions of a significantly higher quality than students from the CONTACT-2 control condition and they had significantly higher learning performance scores. During this testing session, students' conceptions were only activated before and after studying the text: in this case, students had to initiate the other learning activities aimed at conceptual change without external support. Students from the condition "scaffolding per instructional step" seemed to be better prepared for this than students from the CONTACT-2 control condition. In our view, this could be explained by the fact that the CONTACT-2 condition had been characterized by a constant, high degree of external control. Because of this, these students did not seem to be able to initiate and employ the various CONTACT-2 activities themselves: they were not trained to do so. Students from the condition "scaffolding per instructional step", on the other hand, seemed to be able to regulate their own learning aimed at conceptual change because external control had been gradually "scaffolded" during the training. Students from the other experimental condition, "scaffolding of the number of steps", also had higher learning performance scores than students from the CONTACT-2 control condition: for them, external control had been "scaffolded" during the training as well. Moreover, students from both experimental conditions had been informed that

they had to learn to activate their own prior knowledge and to construct correct conceptions without external support. Because of these characteristics, both "scaffolding" procedures seemed to be more effective than the original CONTACT-2 strategy in enhancing students' ability to initiate and employ learning activities aimed at conceptual change.

Furthermore, we assumed that the stage of the "fading" procedures of the two "scaffolding" conditions would affect the quality of students' developing conceptions and their learning performance. This hypothesis was confirmed by the training sessions data. During the first stage of the training, the condition "scaffolding of the number of steps" led to final conceptions of a higher quality than the other two conditions. During the next stages, however, the condition "scaffolding per instructional step" led to the best final conceptions. The quality of the final conceptions of the students from the condition "scaffolding of the number of steps" decreased dramatically, as the training proceeded. Thus, in this respect, the condition "scaffolding per instructional step" proved to be more effective than the CONTACT-2 control condition and the condition "scaffolding of the number of steps".

Apparently, reducing the number of instructional steps (as in the condition "scaffolding of the number of steps") was indeed too drastic: it seemed to result in "destructive frictions" leading to conceptions of a lower quality (see Lohman, 1986; Vermunt, 1992). Therefore, in our view, external support should not be withdrawn until the students are able (or prepared) to perform the corresponding learning activities themselves. In this respect, the other experimental condition "scaffolding per instructional step", in which the number of instructional steps stayed constant but external control had been reduced per step, appeared to be better tuned the actual level of self-regulated learning of the student (see Biemans and Simons, 1992): this "scaffolding" condition seemed to result in "constructive frictions" and, thus, in conceptions of a higher quality.

With respect to the quality of students' conceptions after the seven training sessions and their ability to apply these conceptions, both "scaffolding" conditions led to higher scores than the CONTACT-2 control condition during the first half of the training. Probably, this was caused by motivational factors (see also Pintrich, Marx and Boyle, 1993): students from both experimental conditions had been informed that they had to

learn to activate their own prior knowledge and to construct correct conceptions without external support, in other words, to learn in an active way. During the second half of the training, scores of the students from the three conditions became more and more comparable. The same pattern could be traced with respect to students' learning performance. At this point, however, it should be noted that students from both "scaffolding" conditions received considerably less external help than students from the CONTACT-2 control condition during the last stages of the training but were nevertheless able to achieve comparable learning results. In our view, this should be considered as a positive training effect as well. Moreover, students from both "scaffolding" conditions spent less time during the second half of the training than students from the CONTACT-2 condition.

To conclude, the findings of the present study were generally in line with our hypotheses concerning learning-to-learn training procedures (see Biemans and Simons, 1992). "Scaffolding" (see also Reeve, Palincsar and Brown, 1987) seems to be a fruitful instructional approach to teach students how they can initiate and employ learning activities aimed at conceptual change, provided that the "scaffolding" procedure is based on the actual level of self-regulated learning of the student. In this way, "constructive frictions" (see Vermunt, 1992) can be created and the quality of self-regulated learning as well as learning performance can be improved. In the context of our last study, this meant that the experimental condition "scaffolding per instructional step" was most effective in most learning situations (varying with respect to the degree of external control being provided): this condition appeared to lead to the highest degree of cognitive flexibility.

In other words, with respect to learning-to-learn training procedures aimed at conceptual change, a learning environment characterized by a rather high degree of external control seems to be most appropriate to start with. External control should not be withdrawn until students are able (and prepared) to initiate and perform the learning activities being required: if the degree (or the kind) of the external support is not adequate to serve the student's needs, "destructive frictions" and poorer learning performance are likely to be the result (see also Lohman, 1986). When these conditions are met, however, it seems possible to design effective training procedures aimed at "learning for conceptual change".

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List of key words

Computer-assisted instruction

Conceptual change

Learning to learn

Prior knowledge activation

Process-oriented instruction

Reading comprehension

Self-regulation